Climate Modeling's Fudge Factor Comes Under Fire

In climate modeling, nearly everybody cheats a little. Although models of how the ocean and the atmosphere interact are meant to forecast the greenhouse warming of the next century, when left to their own devices they can't even get today's climate right. So researchers have tidied them up by "adjusting" the amount of heat and moisture flowing between a model's atmosphere and ocean until it yields something like the present climate. But, as usual, cutting corners can eventually catch up with you.

In a study now in press at the *Journal of Climate*, Mototaka Nakamura, Peter Stone, and Jochem Marotzke of the Massachusetts Institute of Technology (MIT) report that they deliberately introduced an error into a climate model, then seemingly adjusted the error away, only to find that it still hampered the model's ability to predict future climates. The implication that flux adjustments disguise—but may not correct—a model's underlying defects won't surprise other climate modelers. Most agree with Warren Washington of the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, who says the practice "makes your model look better than it really is; it could cover up deficiencies."

"No one enjoys using it," adds NCAR's Gerald Meehl, who avoids making flux adjustments in his work with Washington. But for the moment, Meehl says, researchers have little choice if they want to begin their climate-change simulations from a realistic starting point. In the long run, though, the solution won't be fudging—it will be "to improve the components [of the models]," he adds. And there are already signs that, as increasing computer power opens the way to more refined models, Meehl's colleagues may be able to cut back on the fudging, if not renounce it entirely.


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Sea meets sky. The fluxes of heat and moisture that generate storms like this one are partly fictitious in many climate models.

Ironically, the need for the fudge factor grew out of earlier efforts to make climate models more sophisticated. Until about 20 years ago, climate modelers simulated the atmosphere on its own, without trying to include a realistic component representing the world ocean. These atmospheric models did fairly well at recreating today's climate. But their value for forecasting was limited because their developers had to specify how the ocean was influencing the atmosphere—for example, how warm the sea surface was and therefore how much heat the ocean would release to help power atmospheric circulation. And because this input had to be based on observations of the present-day ocean, the models could not provide a clear window on the future.

The answer was to couple the atmospheric models with equally realistic models of the world ocean, so these two major players in climate could interact. But that left the job of calculating the interactions of the ocean and the atmosphere to the less-than-perfect models themselves. If the atmospheric component made more clouds than in the real world, not enough sunlight would get through to warm the ocean; if ocean currents did not carry enough warm water poleward, high latitudes would be too cold.

The result was that even when a coupled model was set up to simulate the existing climate, it would drift away to something quite unreal. In the 1989 version of the NCAR coupled model, for example, wintertime ocean temperatures around ice-bound Antarctica were 4°C above zero, while the tropical ocean was as much as 4°C too cold.

Some modelers have chosen not to tweak their models, in the hope that climate simulations would respond accurately to increasing greenhouse gases even though the models can't mimic the baseline climate. Washington and Meehl, for example, run the NCAR coupled model with all its blemishes in plain sight. But most modelers go the tweaking route, adjusting the flows of heat and moisture between ocean and atmosphere to nudge the model into agreement with today's climate. Actually, shove might be a better word than nudge: Adjustments have typically been at least as big as the model-calculated fluxes—in some places five times as large.

Although modelers have long felt uneasy about large flux adjustments, no one had studied their effects on coupled models because running a full-scale coupled model takes so much computer time. The MIT group developed a geographically simplified model that still reproduces many of the complex interactions between atmosphere and ocean found in more detailed coupled models. The group then deliberately inserted an error into the model that made it transport too much moisture through the atmosphere.

The error spelled trouble for climate forecasts made with the model. Because of the altered moisture transport, the model's version of the "conveyor belt" of currents in the Atlantic Ocean, which plays a crucial role in climate by ferrying the heat that warms northern Europe, was much weaker than in the unaltered model. By making a flux adjustment, the MIT workers were able to fix the model so that it matched the present climate. And yet, says Stone, "the error is still in the model"—making the conveyor belt appear more sensitive to climate change.

That result shouldn't be used as a blanket condemnation of flux adjustments, says modeler Syukuro Manabe of the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey. In some cases, he says, they do compensate neatly for underlying errors. For example, because of a computational bias, the GFDL model assumed an unrealistically large amount of precipitation in high latitudes—an error he and his colleagues corrected for with a moisture flux adjustment. Compensating in kind for a fictitious climate feature is harmless, he says.

In any case, Manabe adds, large flux adjustments may soon be a thing of the past, thanks to increases in computer power. The higher spatial resolution in the latest version of the GFDL model, for example, produces a stronger, more realistic sinking of dry air in the subtropics. That, plus fine-tuning of the model's clouds to make them agree with satellite observations, have greatly reduced the size of the heat-flux adjustment, Manabe says.

But the MIT results are a reminder of the pitfalls on the way toward the ultimate goal of a model coupling all the components of climate—not just ocean and atmosphere, but also ice, land, vegetation, and geochemical cycling. "People are now becoming aware that you can put all the components together if you have a lot of computing power," says Meehl, "but we know from our own experience with ocean, atmosphere, and ice components that it's a major step from components to having it look like Planet Earth."

–**Richard A. Kerr**